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COMPARISON OF TEST STANDARDS USED AT "CEAL" FOR EVALUATION OF ANTI-STATIC PROPERTIES IN FIRE-RESISTANT MATERIALS

N.K. Sarin
Canadian Explosive Atmospheres Laboratory (CEAL)

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COMPARISON OF TEST STANDARDS USED AT "CEAL" FOR EVALUATION OF ANTI-STATIC PROPERTIES IN FIRE-RESISTANT MATERIALS

by

N.K. Sarin*

ABSTRACT

The surface electrical resistance which is an indicator of electrostatic hazard was determined for several fire-resistant materials employed in underground mines. Two test standards were investigated, namely the National Coal Board (NCB) Spec 158/80 and European Standard EN 50014. The objective of this investigation is to clarify the limits of electrical resistances permissible in each case, and to assist in developing a more realistic standard for Canada.

The report indicates that the European method always generated lower surface resistance values compared to the results obtained by using NCB Spec 158/80. The ratio of these resistances for the same materials is around 1.7 on the average.

It is concluded that 500 MΩ (megohms) limit mentioned in divisional report ERP/MRL 80-21(TR) was an error. However, the Canadian Atmospheres Laboratory (CEAL) has been consistantly using 120 MΩ limit for certification purposes in order to achieve a better safety margin. Recommendations are made to study other variables influencing test results and to consider alternative grounding techniques for safe discharge of static electricity. The need for a National committee to develop a Canadian standard is suggested.

Drawings of various test layouts, equipment and fixtures employed are presented at the end.

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*Investigation Officer, Canadian Explosive Atmospheres Laboratory, Mining Research Laboratories, CANMET, Energy, Mines and Resources Canada, Ottawa.

COMPARAISON DES NORMES D'ESSAI UTILISÉES AU LABORATOIRE CANADIEN DE RECHERCHE SUR LES ATMOSPHÈRES EXPLOSIVES POUR L'ÉVALUATION DES PROPRIÉTÉS ANTISTATIQUES DE MATÉRIAUX IGNIFUGES

par

N.K. Sarin*

RÉSUMÉ

La résistance électrique superficielle, indice de risque électrostatique, a été déterminée pour certains matériaux ignifuges utilisés dans les mines souterraines. La norme Spec 158/80 du National Coal Board et la norme européenne EN 50014 ont fait l'objet d'une évaluation. Le but était de déterminer plus clairement les limites des résistances électriques admissibles dans chaque cas, afin d'aider à la mise au point d'une norme plus réaliste pour le Canada.

Il a été constaté que la méthode d'essai européenne donnait toujours des valeurs plus faibles de la résistance superficielle que celle de la Spec 158/80. Le rapport des résistances obtenues pour les mêmes matériaux s'établit en moyenne à environ 1,7.

Les études effectuées permettent de conclure que la limite de 500 MΩ (mégohms) mentionnée dans le rapport ERP/MRL 280-21 (TR) était une erreur. Le Laboratoire canadien de recherche sur les atmosphères explosives a cependant toujours utilisé la limite de 120 MΩ aux fins d'homologation afin d'assurer une meilleure marge de sécurité. Il est recommandé d'étudier d'autres variables qui influent sur les résultats des essais et d'examiner la possibilité d'adopter d'autres techniques de mise à la terre pour assurer la décharge sans danger de l'électricité statique. Il est suggéré qu'il serait utile de créer un comité national pour élaborer une norme canadienne.

Des schémas illustrant les montages, le matériel et les accessoires utilisés pour les essais sont donnés à la fin du rapport.

* Chercheur, Laboratoire canadien de recherche sur les atmosphères explosives, CANMET, Énergie, Mines et Ressources Canada, Ottawa.

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1.0 INTRODUCTION

In almost all industrial environments an accidental release of electrostatically charged energy can potentially cause explosion hazards particularly in dust laden storage silos or gassy atmospheres in underground mines. For this reason, the federal department of Energy, Mines and Resources provides a testing and certification service to the mining industry for approval of various fire-resistant materials which are prone to building up of electrostatic charges due to the friction of air or gases being transported through them. Amongst these materials are flexible plastics, rigid PVC, fibreglass reinforced plastics and rubber compounds for the construction of conveyor belts, gas extraction pipes and ventilation duct materials. Most of these materials are either semi-conductors or insulators. Efforts have been made in several mines to continuously discharge the electrostatic energy by suitable grounding techniques, however the CEAL requirement to limit the electrical resistance of these materials to the present levels provides an additional margin of safety against mine accidents attributable to the electrostatic discharge (2).

Experience has indicated that almost 80% of the products submitted to CEAL for evaluation to date, did not meet the requirements of the existing standards. Several techniques are available for producing anti-static materials, however the additional cost of manufacturing are discouraging factors. The following methods have been tried so far:

a) Mixing of carbon black and other anti-static additives in the product formulation.

b) Fine wire mesh sandwiched between two layers of PVC or other coating material while grains of wire mesh project to the surface of the material on both sides.

c) Surface coating of base fabric with a fine layer of anti-static chemicals.

1.1 BACKGROUND

EMR commenced certification of anti-static duct materials for mines approximately seven years ago (4). In the absence of a Canadian standard, this laboratory had chosen to use two test standards, i.e., NCB Spec 158 for flexible materials (3) and European Standard EN 50014 for rigid duct materials (5). These standards were specifically designed by the originators for evaluation of conveyor belts and electrical enclosures, respectively.

This investigation was prompted because two separate figures were quoted by CEAL as the acceptance limit of surface resistance in case of the European Standard. Although the European Standard specifies 1000 MΩ limit, CEAL has been using 120 MΩ for certification purposes. More confusion occurred when 500 MΩ was mentioned as the limit in divisional report ERP/MRL 80-21(TR). This created an urgent need to clarify the situation and to assist in the development of a very precise single standard for the purpose. Such work has not been undertaken prior to this report.

2.0 TESTING ENVIRONMENT - VARIABLES

Readings from the measuring instrument "MEGGER" are subject to scatter due to several variables such as relative humidity, atmospheric temperature, soaking time of samples in test environment, contamination due to improper application of conducting media and the presence of conductive dust particles. For the purpose of this investigation the test sample areas were the same during both test methods which were applied with a short time interval. This should practically eliminate most of the variables mentioned above. Special precautions have been taken in preventing contamination due to spreading of conducting liquid agent over the plastic fixtures (Figs. B & C), employed to separate and precisely locate the metal electrodes.

Insulation of the plastic fixtures (Figs. B & C) were periodically checked at several locations to ensure that no electricity was bypassing the test sample between the terminals. These pieces were cleaned with diluted alcohol if found contaminated and dried before reuse. During this investigation, only flexible and flat materials (i.e., plastics, textile brattice cloth and conveyor belts of various rubber compounds) were selected for convenience as opposed to using rigid pipes having curved surfaces.

Perfect repeatability of results under similar conditions using different test spots on the same surface of these materials is generally not achievable due to difficulty in manufacturing a perfectly homogeneous mix of the product formulation and lack of precise control on test environment. However, repeatability of results on the same spot is expected to be excellent provided the test conditions are maintained constant.

3.0 CEAL VERSION OF NCB SPEC 158/1980 PART 7 - METHOD OF TEST FOR ELECTRICAL RESISTANCE (3)

3.1 GENERAL

This specfication was developed by NCB mainly for testing conveyor belts (3), however CEAL has adopted it for anti-static testing of flexible duct materials as well. CEAL has also devised a plastic fixture (Fig. B) for concentric location of two test electrodes which is not a requirement of this standard.

3.2 APPARATUS

An electrode system consisting of a 25 mm diam brass cylinder and a brass ring of 125 mm ID and 150 mm OD is placed concentrically on the surface of the sample with the aid of a plastic fixture shown in Fig. B. A liquid contact agent of heavy polyethylene glycol and water is used to ensure good contact with the surface. The resistance is measured between the two electrodes by means of an insulation resistance measuring instrument with a range of 1 to 10,000 MΩ (Megohms) and an applied potential of between 40 and 1000 V DC.

3.3 SAMPLES

Samples of not less than 2 m^2 are selected from material in sheet or roll form. Six pieces of 300 mm x 300 mm are cut and soaked in the test environment for at least 12 hours before starting the test.

3.4 PROCEDURE

The prepared samples are placed flat on a polyethylene sheet spread over a flat wooden surface. The sample surface is rubbed clean with fuller's earth (BP grade), washed with clean water and dried before placing the electrodes on them. The instrument needle is set at ∞ to indicate perfect insulation before connecting terminal wires to the brass electrodes. A minimum of three readings are taken on each side of the material.

3.5 TEST CONDITIONS

a) Ambient Temperature = 20° ± 2°C

b) Relative Humidity = <70%

c) The potential is applied for no more than 5 minutes

d) The outer brass ring is always connected to the earthed or low potential terminal.

3.6 ACCEPTANCE CRITERIA

An average of three readings on each surface of the material shall not exceed 300 MΩ.

Note: For details on conductive liquid agent, please refer to NCB Spec 158/1980.

4.0 CEAL VERSION OF EUROPEAN STANDARD EN 50014 - INSULATION RESISTANCE OF PLASTIC MATERIALS (5)

4.1 GENERAL

This method was adopted by CEAL for testing curved surfaces of rigid pipes, etc. Two parallel strips of conductive paint applied 10 mm apart x 100 mm long serve as the electrodes (Fig. B). For convenience of testing flat materials in this study, the writer designed and experimented with a new fixture of brass bars held 10 mm apart by non-conducting flat Plexiglas (Fig. C). However, the flat brass bars had to be replaced with wedge-shaped brass bars (Fig. D) in order to produce only line contact with the test spots without fear of contamination due to the conducting liquid agent if accidently it may short circuit brass conductors via insulating Plexiglas (Fig. C). However, with the wedge-shaped bars (Fig. D), we use a 2 kg weight in order to achieve proper surface contact. No conductive paint is necessary.

4.2 APPARATUS

Resistance between the parallel conductors is measured with the same instrument as described under section 4.2 for NCB Spec 158 except that a voltage of 500 ± 10 V DC is applied for one minute for each trial.

4.3 SAMPLES

Minimum sample size is 300 mm x 300 mm and samples are soaked in the test environment for at least 24 hours before testing. The standard allows a minimum sample size of 60 mm x 150 mm.

4.4 PROCEDURE

The procedure is similar to the one described in section 3.4, however the test spots were also the same and tested immediately after the NCB test for each trial in order to minimize the number of test variables. Variations in voltage were assumed small and therefore ignored.

4.5 TEST CONDITIONS

a) Ambient Temperature = 20 ± 2°C

b) Relative Humidity = 50% ± 2% required as per standard, but the tests were carried out in an open environment without regard to humidity because this study is conducted for comparing test results of two methods under the same environment.

4.6 ACCEPTANCE CRITERIA

The surface resistance in any trial shall not exceed 1 GΩ at 23°C and 50% relative humidity. CEAL has been using 120 MΩ acceptance limit for product certification purposes. An average of three readings at three different spots on the same surface is obtained for comparison with the acceptance limit.

5.0 OBSERVATIONS AND DISCUSSIONS

Some variation in recorded values was observed with the same material tested at three different spots. Each resistance value shown in Appendix A reflects an average of at least three readings. We have noticed that standard deviations range between 10-50% of the mean values. However, these variations are only approximations obtained by using three values for each sample analysis and assuming that these values follow a normal distribution pattern. This observation will be a concern when the mean value is close to the established acceptance limits and the standard deviation is relatively high. This is generally a very rare occurrence. Average value of the ratio of resistances obtained from these methods is 1.7. This lies between ratios of 2.5 and 0.60 obtained by dividing the 300 MΩ acceptance limit in NCB Spec by the two acceptance limits of 120 MΩ and 500 MΩ respectively mentioned in this report for the CEAL version of the European standard. Since the experimental value of the ratio (1.7) is closer to the established ratio of 2.5, it would indicate

that 120 MΩ is a better acceptance limit for the European method than the 500 MΩ as indicated in CEAL report ERP/MRL 80-21(TR).

Theory would suggest that the electrical surface resistance is directly proportional to the linear distance between the electrodes (i.e., the resistances recorded by NCB method should be higher than those obtained from the European test method), which generally agrees with most of the experimental value in Appendix A. Consequently, the acceptance limit in the case of the NCB test should be higher than the limit indicated in the European test. By the same logic, if 300 MΩ is correct, then proportionately the European limit should be $\frac{10}{50} \times 300 = 60$ MΩ, which is not true. Since the ratio of distances between electrodes in each method is not compatible with the ratio of the acceptance limits, there are obviously other influencing factors e.g., the mode of current transmission via low resistance areas randomly scattered in the material.

It was also noticed that the resistance values recorded on the outer surfaces of ventilation materials is generally higher than those observed on inner surfaces. For analysis of the results, only the outer surface values have been considered. Also the resistance values recorded at the upper end of the instrument scale cannot differentiate between two methods due to scale compression. On the lower end, the difference in recorded values is not significant in relation to the acceptance limits. Very rarely the ratio of electrical resistances is found lower than 1.0. The difference between the average ratio of resistances (1.7) obtained from experimental results and the ratio of acceptance limits (2.5) of resistances from CEAL versions of both test methods may be attributed to different safety margin used in each case. Statistical analysis of the individual readings for each sample tested was carried out. The value of standard deviations are less than the differences between various ratios (r). Therefore, the wide scatter of ratios (r) suggest that values obtained from any one method cannot predict the values possible from the other method. For these reasons, a choice must be made between the NCB and the European test procedures and the same be modified for CEAL certification purposes. The advantages include simplicity of testing and removal of errors caused by contamination of electrodes due to use of liquid contact agents etc. The accuracy and precision of the measuring instrument is influenced by the discrimination of the measuring scale and since the scale ranges between 0–∞, it is obvious that the lower end of the scale up to 500 MΩ pro-

vides more precision due to better scale divisions as compareed to those read beyond 1000 MΩ. Consequently errors up to 100 MΩ are possible beyond 1500 MΩ readings. Nontheless, the scatter of values obtained for the same sample are greater than the precision of the instrument at different levels of the scale. This would indicate that perfect homogeneous mix of the product is not possible which accounts for these variations and consequently, repeatability of readings at different spots of the same material is not achievable even under identical test conditions. However, repeatability of readings on the same spot of the same material is excellent (within the measuring capability of the instrument).

Research tests were carried out in an uncontrolled environment at CEAL without regard to variations in humidity, whereas both NCB and European standards specify this requirement precisely.

The average values of electrical surface resistances are currently used to determine material suitability which is not consistant with the criteria used for evaluation in case of fire-resistant requirements for flexible duct materials. One should be concerned with the worst possible mine conditions (i.e., in this case the highest value of electrical resistance should represent the worst condition). It is logical therefore to also compare the highest value with the established limit of surface resistance for selecting or rejecting such materials.

6.0 CONCLUSION

With the available facilities at CEAL, it has not been possible to strictly adhere to NCB Spec 158/1980 or European standard EN 50014 for evaluation of anti-static properties of fire-resistant (non-metallic) materials. However, attempts have been made to improvise a temporary humidity chamber without precise control on the humidity levels and the test temperature. Consequently, the CEAL version of the existing standards was applied as discussed in this report, however the limit of electrical surface resistance (120 MΩ) in the case of the European standard, provides relatively better safety margin than the 500 MΩ limit as specified in report ERP/MRL 80-21(TR). Therefore, retesting and review of the materials tested in the past is not necessary.

7.0 RECOMMENDATIONS

1. Report ERP/MRL 80-21(TR) must be revised to replace the existing standard and procedure with a cross reference to the CEAL version of both standards as presented in this report in order to serve as interim requirements at CEAL.
2. A modified CEAL version of the European standard should be adopted as the only final standard for consistancy and uniformity in test results in concurrence with the manufacturers and users of such materials.
3. A suitable humidity control chamber must be obtained for sample conditioning prior to testing.
4. A research investigation should be undertaken to study the influence of sample soaking time, ambient humidity, temperature and dust in the test environment.
5. Consideration must be given to the study of the methods and mechanisms available to safely discharge static electricity in explosive atmospheres with a view to recommend or add to certification requirements a second line of defense against accidents attributable to static electricity.
6. A national committee should be formed to assist in the development of a Canadian standard compatible with the Canadian mine environment.

8.0 ACKNOWLEGEMENTS

Thanks are extended to CEAL manager Mr. J. Bossert for his guidance and to Dr. K. Mintz for his constructive comments.

9.0 REFERENCES

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2. Rabkin, E. "Static electricity and methods for its elimination"; T.I.S. Report #31; National Research Council, Ottawa.

3. NCB - specification 158/1980 concerning anti-static testing of conveyor belt materials.

4. Discussion with laboratory manager at CEAL/EMR.

5. Electrical apparatus for potentially explosive atmospheres - general requirements; Reference European standard EN 50014, Ed. 1; March 1977.

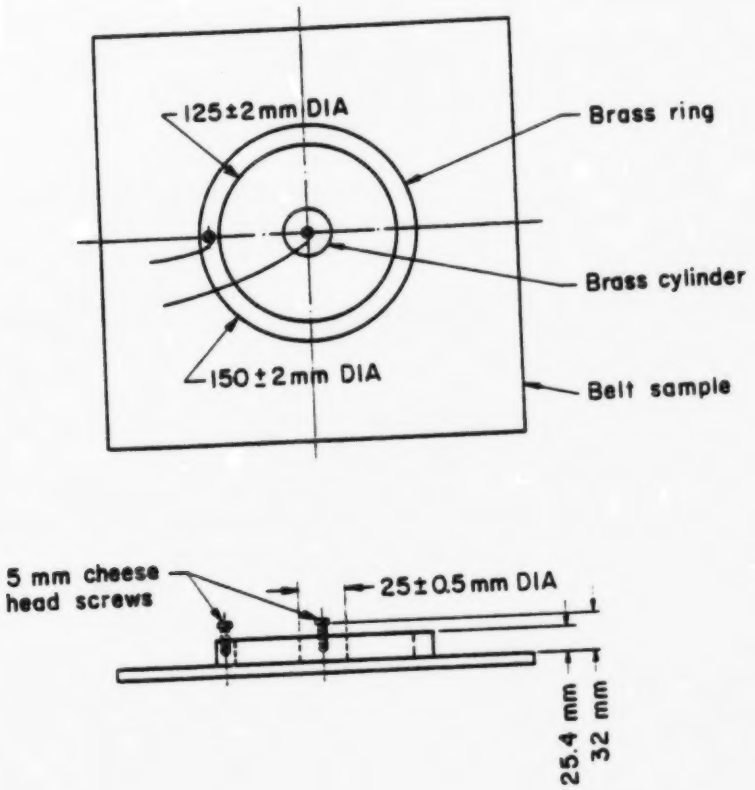


Fig. A - Test layout NCB Spec 158

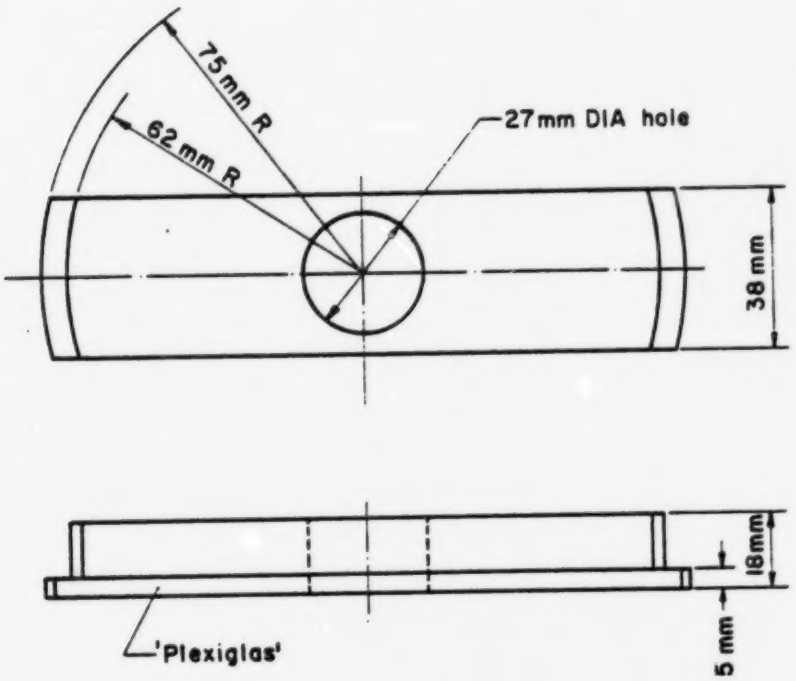


Fig. B - Attachment for electrostatic test (NCB 158)

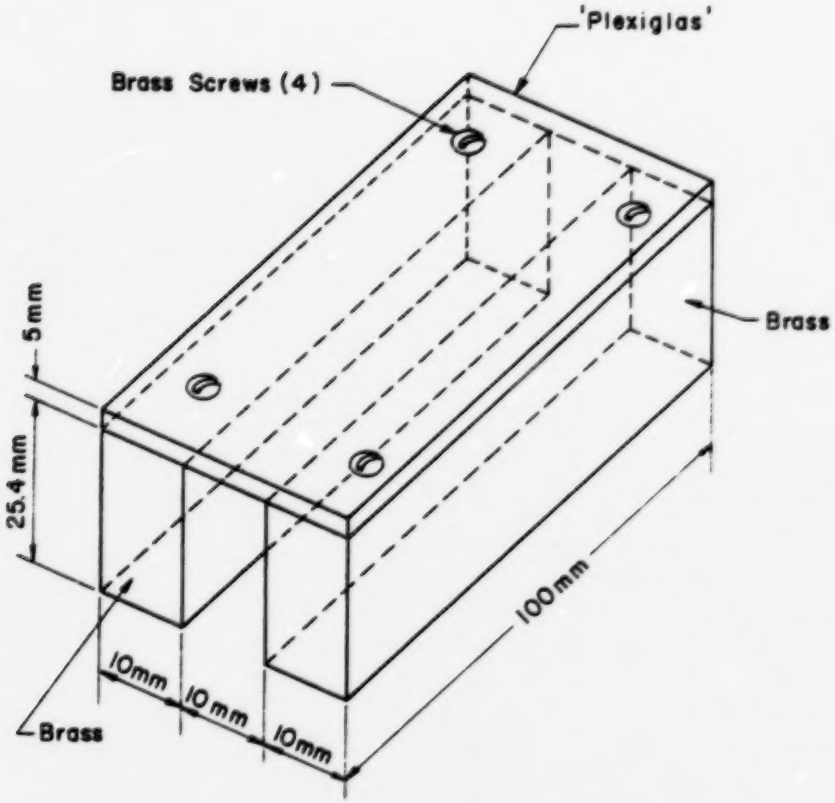
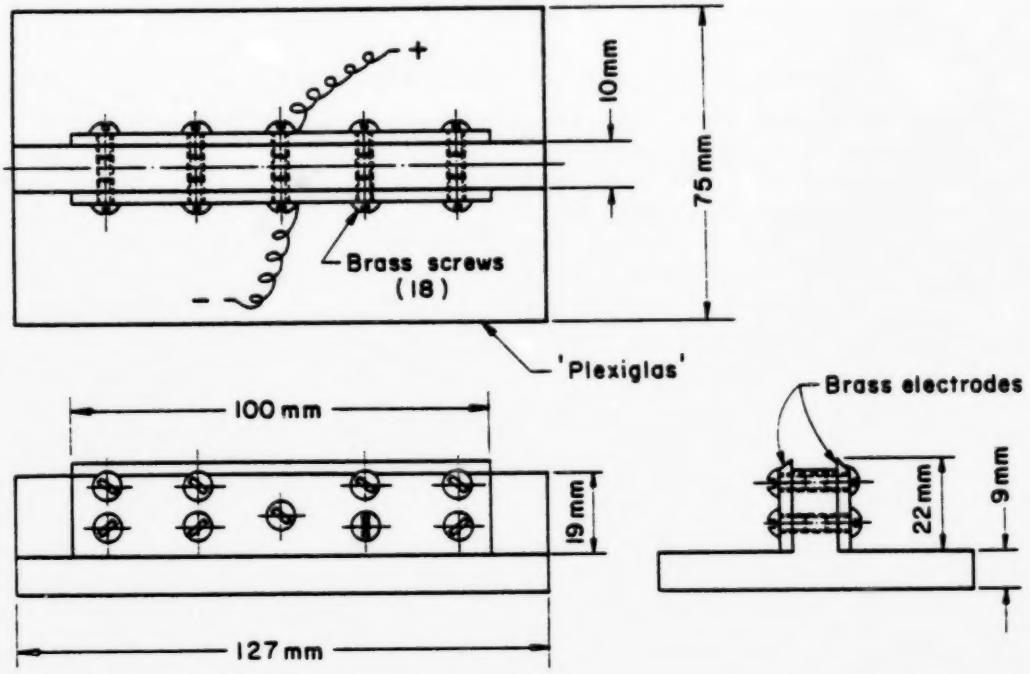


Fig. C - Apparatus for testing electrical resistance



CEAL Apparatus for Testing Electrical Resistance

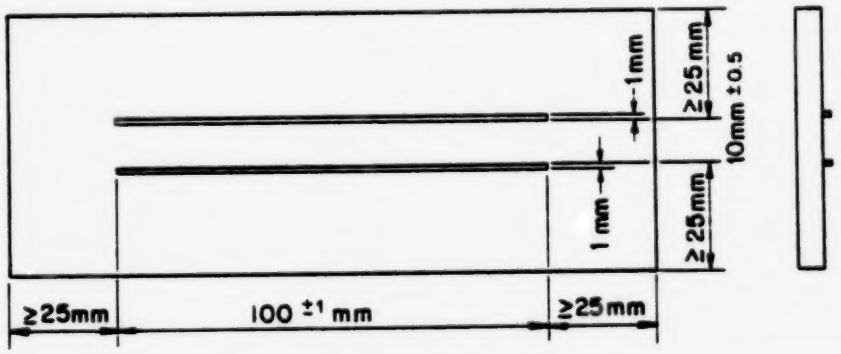


Fig. D - CEAL apparatus for European test

APPENDIX A

Electrical (surface) resistance in MΩ

All resistance values are average of three readings on same sample

Surface Sample #	Values using "CEAL" version of NCB Spec-158 (NCB) Outer	Inner	Values using "CEAL" version of European standard (E.S.) Outer	Inner	Ratio of values NCB/E.S. Outer	Inner	Type of material and reference
1	7000.	7000.	3000.	3000.	2.3	2.3	(yellow) PVC conveyor
2	12.1	2.8	18.0	2.40	0.7	1.2	5/8" belt conveyor
3	0.01	0.005	0.008	0.005	1.3	1.0	1" thk rubber
4	0.09	0.030	0.085	0.03	1.1	1.0	1/2" thk rubber
5	0.06	0.010	0.1	0.03	0.6	0.4	1/4" thk rubber
6	0.10	0.030	0.03	0.045	3.3	0.7	1/4" thk sample # 1
7	0.025	0.040	0.03	0.03	0.9	1.3	1/3" thk rubber
8	11.6	-	4.94	-	2.4	-	Brattice cloth SR #52
9	900.0	-	700.	-	1.3	-	PVC coated jute cloth SR #51
10	1500.	-	412.	-	3.8	-	Yellow PVC SR #55
11	1300.	-	616.	-	2.8	-	Yellow PVC SR #56
12	500.	-	541.0	-	1.02	-	Yellow PVC SR #57
13	4.0	-	3.5	-	1.2	-	Black plastic SR #50

Δ Ratio of Resistance(r) = $\frac{\text{Surface Resistance/NCB Spec 158/80}}{\text{Surface Resistance/European Standard}}$

APPENDIX B

Comparison of test standards

	Testing Requirements	NCB-Spec 158/1980 (NCB)	European standard EN 50014 (E.S.)	CEAL test requirements
1	Environmental Humidity Level	65 ± 5%	50 ± 2%	<70%
2	Atmospheric Temperature	20 ± 2°C	23°C	<20°C
3	Voltage Between Terminals	40-1000 V DC	0-500 ± 10 V DC	40-1000 V DC
4	Waiting Time Before Reading	<5 min	1.0 min	Nil
5	Minimum Sample Soaking Time	2 hours	24 hours	12 hours
6	Sample Cleaning Before Test	Clean with Fuller's earth, then with distilled water and dried	No mention	Same as NCB test
7	Limit of Surface Resistance	300 MΩ	1000 MΩ	120 & 500 MΩ for E.S., 300 MΩ for NCB
8	Voltage Stability	No mention	Must be sufficiently steady	No mention
9	Measuring Instrument wall power	Megger tester Hooked to 110 V Tester	Hand cranked portable Megger	Hand cranked and wall unit
10				

Note: NCB and European standards are more precise in their procedures and requirements, however CEAL requirements for anti-static properties of fire-resistant materials are rather very general, inaccurate and flexible.

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